AIR FORCE OFFICE OF SCIENTIFIC RESEARCH [AFOSR]

Research HIGHLIGHTS

MAR APR 98

1997 Physics Nobel Prize Rooted in Air Force Support

This year's Nobel Prize winning research in physics is likely to benefit Air Force with a wide array of new capabilities in navigation, guidance, accelerometers and electronics.

The prize was awarded in October to Dr. Steven Chu of Stanford University, one of three physicists sharing the prize for their "development of methods to cool and trap atoms with laser light." The Air Force Office of Scientific Research (AFOSR), together with the National Science Foundation, has funded Dr. Chu's research in the techniques of optical cooling and the trapping of atoms since 1988.

This method to cool and trap atoms with laser light provides the foundation for atom interferometers, atom lasers and more precise frequency standards — the basis for atomic clocks.

These devices will be used to benefit the Air Force in the following areas:

- navigation, guidance and control systems (using atom interferometers for accelerometers and rotation sensors)
- smaller electronic circuits with greater density (using atom lasers)
- covert and encrypted communications (using precise frequency standards), and
- fundamental physics study — a foundation for future breakthroughs

"Dr. Chu is an idea man who comes up with ideas that work."

BELOW:* *Dr. Steven Chu, 1997 Nobel Prize Winner in Physics (pictured center) with students from Stanford University

Greater precision in frequency standards will have a major impact on atomic clocks with an anticipated 100-fold increase in accuracy. "The most precise physics experiments are done with atomic clocks. The frequency standard... is sort of the stake in the ground of all science. Any ultra-precise measurement goes back to that standard... an improvement of that time standard has ripples that find their way

continued on page 2...

Dr. Chu, The Nobel Prize, and AFOSR

throughout all of precision physics in all areas," Prof. Chu said. Atomic clocks are used in space and earth navigation to accurately pinpoint position.

Dr. Chu's research discoveries are influencing a variety of other branches of science and offer additional benefits:

- a new way of understanding polymer behavior (coatings, friction, injection molding)
- direct studies of biological interactions (DNA behavior, bacterial interactions)
- insight into novel forms of matter (Bose Condensation, atom interferometer), and
- a legacy of graduate students to enrich the U.S. talent pool

AFOSR program mangers Dr. Howard Schlossberg and Dr. Ralph Kelley continued Dr. Chu's research support because of the extraordinary promise it demonstrated by his accomplishments. "When we look at other Nobel Prize winners we've funded in the past like Dr. Charles Townes who invented the ammonia maser, we often learn of the major significance after the fact — many years later when history tells us what applications have developed," says Dr. Schlossberg.

"Technology is based on new understanding, not the continuous recycling of old knowledge," says Dr. Kelley. "The more we know, the better the technology we can develop. Dr. Chu is an idea man who comes up with ideas that work."

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For more information:

- Technical Background
- For more on applications
- Prize built on legacy of physicists' work

See our website at:
HYPERLINK http://www.afosr.af.mil

AFOSR has sponsored 40 Nobel Laureates in physics and chemistry since its founding in 1951. Highlights are being developed on our website.

GE uses AFOSR research in next-generation turbine bl

New Material Promises Hig

Aircraft engine designers and the Air Force operational community will soon benefit from the rapid research transition of a new material to industry for manufacturing future, high-temperature (900° C) gas turbine engines.

Among the intermetallic materials under recent study for possible application in aircraft engines, gamma titanium aluminides (TiAl) are showing the most promise. Among its many positive properties (stiffness, high strength, high-temperature oxidation stability, and creep resistance), the material is more than 50% lighter than the currently used nickel-based superalloys. Use of this lighter, higher-specific stiffness material will allow:

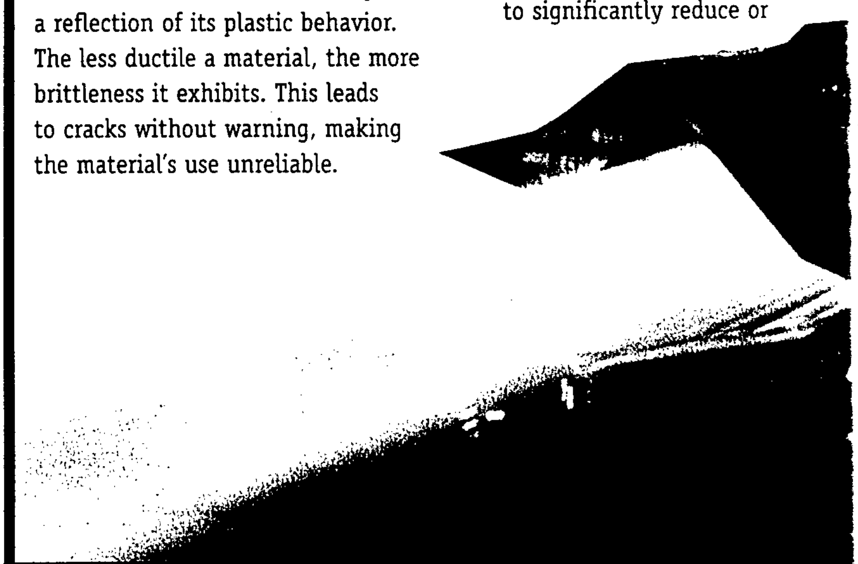
- reduced engine weights (with increased thrust-to-weight ratios),
- design of smaller engine components,
- more efficient engine operation,
- and greater savings in fuel consumption.

However, one major, critical concern regarding the materials use in gas turbine components involves the material's observed low ductility — a reflection of its plastic behavior. The less ductile a material, the more brittleness it exhibits. This leads to cracks without warning, making the material's use unreliable.

In 1995, AFOSR initiated a Partnership for Research Excellence and Transition (PRET) with four universities (Carnegie-Mellon, Ohio State, Michigan and Michigan State and six companies (Allied Signal, Allison Engine Company, General Electric Aircraft Engines, Howmet Corporation, Precision Castparts Corporation, and Rockwell International) to focus on the fundamental issues of the material's microstructu processing, and design that are directly relevant to its transition into production aircraft components.

The PRET program is led by Profs. Tresa Pollock, principal invest gator, and Paul Steif, co-principal investigator, both of Carnegie-Mello University. In just two years, one of their project leaders, Prof. J. Beuth, has achieved significant accomplish ments related to two principal effor which address the ductility issues. Based on integrated modeling and e perimental efforts, his research show

- The material's total failure strain was determined to be in the one two percent range. Though limit TiAl's plastic behavior is sufficie to significantly reduce or



Air Force Fighter [illegible]

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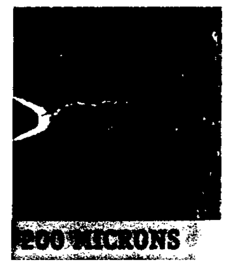
- The material's total failure strain was determined to be in the one to two percent range. Though limited, TiAl's plastic behavior is sufficient to significantly reduce or eliminate stress concentrations in the material. This is important because it is the accumulation of local stress concentrations, which leads to rapid material failure.
- Tests to determine the dependence of ductility on various geometric and material parameters — based on notched and unnotched specimens — show notch strengthening parameters allow the material to function with greater resistance.

While a complete theory is being developed, their findings are already influencing the activities of industrial partners and contributing to the development of future aircraft engines. In 1997, GE used the university data in their final GE90 low-pressure turbine blade design, a highly unusual step as part of a formal design review. The successful transition of this advance is a direct result of the PRET's strong, integrated university-industry partnership. Dynamic program management allows participants and Air Force Research Laboratory researchers to determine the critical issues and redirect the emphasis.



Data from the PRET project on deformation of notched specimens of varying geometries was used as a part of the final low pressure turbine blade design review by General Electric in February of 1997. This is the first time that "outside" data has been considered in this critical phase of implementation. Below are results from straining experiments on notched specimens which show the relationship of local straining, crack initiation and crack growth and their independence on microstructure.

For the technical description, visit our website at:

HYPERLINK http://www.afosr.af.mil

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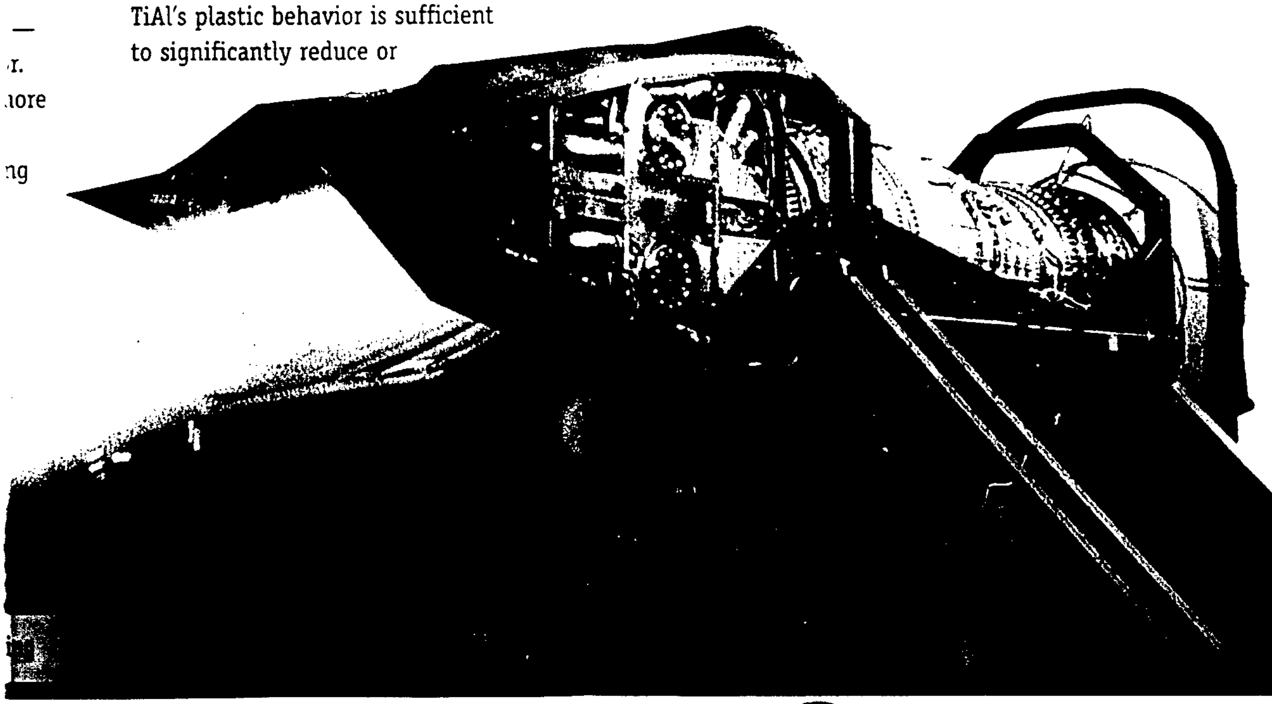

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mance Military Aircraft Engines

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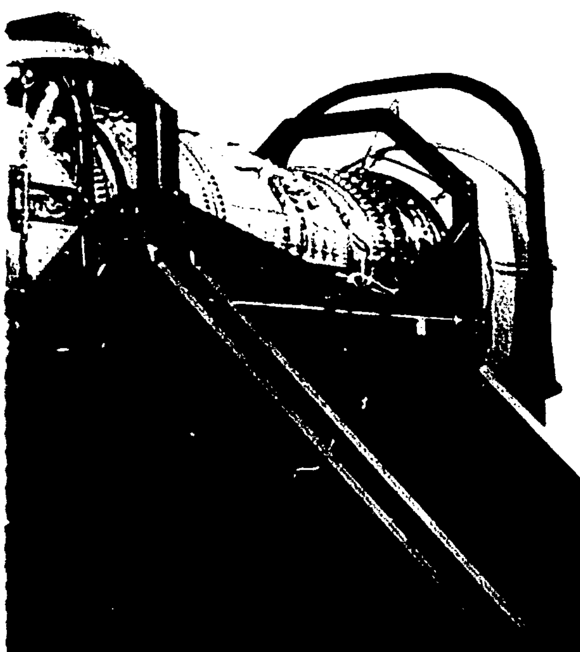

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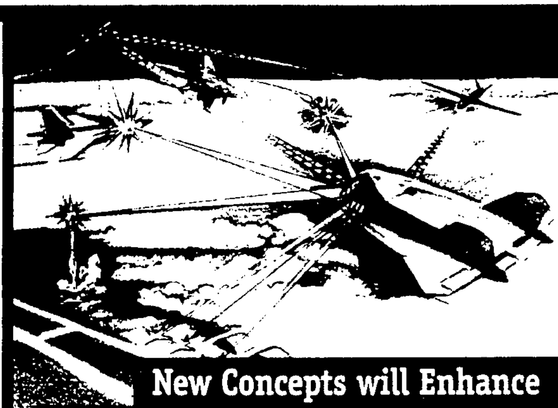

New Concepts will Enhance Aggressive Flight of Uninhabited Combat Aerial Vehicles

Researchers at the California Institute of Technology have developed a new approach to nonlinear control that promises to radically improve the performance of future missiles and uninhabited combat aerial vehicles (UCAVs) engaged in aggressive maneuvers.

Their development of new theoretical and computational tools is providing an extremely effective methodology for computing aggressive trajectories for certain classes of flight systems in real-time: a critical need for greatly enhancing the maneuvering capabilities of future uninhabited combat aircraft.

Professor Richard M. Murray leads the research team conducting this work, part of the AFOSR-sponsored Partnership for Research, Excellence and Transition (PRET) Center for Robust Nonlinear Control of Air Vehicles. Murray also directs the Center, which was established in 1995 at Caltech.

Aggressive trajectory tracking in flight systems requires fast and accurate calculation of the desired attitude and control surface motions needed to complete a maneuver. Traditional flight control systems either rely on pilots for this task — which exploit a human's unparalleled ability to learn the behavior and limits of a system and to operate near the boundaries of achievable performance — or make use of precomputed trajectories and maneuvers. However, in the future, aerial vehicles are destined to be uninhabited, though they will still require high performance in unstructured environments. Pilots will have to remotely control one or several (heterogeneous) aircraft. Future flight control systems must perform commanded maneuvers that push the edge of the achievable operating envelope while respecting the aircraft's dynamical limitations.

continued on back page...

Aerial Vehicles (con't.)

These problems motivated Caltech's new work in nonlinear control theory, which is based on a mathematical property known as differential flatness. Differentially flat systems share an important property: the generation of the system's trajectories can be reduced from a dynamic problem — requiring techniques that are computationally demanding and extremely difficult to implement in real-time — to an algebraic problem — for which tractable computational algorithms can be generated.

Murray and his group are now developing new techniques for characterizing differentially flat systems as well as new algorithms for exploiting flatness to generate trajectories for the system in real time. This is an important step in understanding how to design vehicles with properties that can be exploited by the new nonlinear control techniques.

Dr. Richard M. Murray

Differential flatness is beginning to play a role in the development of control laws for some air-to-missile systems, where high performance in rapidly changing conditions is essential.

The Caltech group has implemented and tested their algorithms for real-time trajectory generation on a small, flight-control experiment which mimics the longitudinal dynamics of a thrust-vectored aircraft, demonstrating substantial improvement over conventional algorithms. Murray's PRET partners — Honeywell, Boeing, Northrop, and Hughes — are currently investigating the use of this technology in more realistic systems.

For more technical information, see Caltech's PRET website at:

HYPERLINK http://www.cds.caltech.edu/~murray/flatness.html

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Research Highlights is published every two months by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission.

NEXT ISSUE

New Air Force Patent for High-Energy Lasers
Dr. Jerry Franck, an Air Force researcher and now manager of the Air Force's Engineer and Scientist Exchange Program (ESEP) and Dr. Wolfgang Riede, a German scientist participating in the ESEP program, have patented a new system for developing high-energy lasers. The laser features a rugged alignment system based on a Stimulated Brillouin Scattering Mirror. Air Force applications may include range finders, designators, and illuminators, and can be used as a source for large laser amplifiers. We'll cover the story in our next issue.

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